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ACTIVE MAGNETOSTRICTIVE SENSOR FOR AUTOMOTIVE HORN OR OCCUPANT WEIGHT SENSOR

RELATED APPLICATIONS

[1] This application claims priority to U.S. Provisional Application No. 60/271,617; filed on February 27, 2001.

BACKGROUND OF THE INVENTION

[2] The present invention relates to an improved system and method for activation of a vehicle horn or other vehicle functions and for detecting the weight of a person seated within a motor vehicle.

[3] Current horn sensor designs have a large variability in force over the operating area of the sensor. In other words, the force needed to activate the horn may vary greatly between two different points on the horn sensor contact surface. Even at a given location on the horn sensor contact surface, the force required may also vary (e.g. two to seven pounds) over operating conditions, such as temperature, etc. Further, the sensitivity level of the sensor cannot be adjusted easily without significant time and expense for retooling.

[4] Current vehicles include an airbag for the driver as well as the front seat passenger. The danger that the passenger side airbag poses to infants in car seats and small children as well as small adults has been well documented. Manufacturers have sought to develop systems that would disable the passenger side airbag if the weight on the passenger seat is below a given threshold, thereby indicating either the presence of an individual for whom the airbag would be dangerous or the absence of any passenger at all.

[5] One known system, described and claimed in U.S. Patent No. 5,739,757, entitled “Vehicle Passenger Weight Sensor,” the assignee of which is the assignee of the present invention, uses a magnetostrictive sensor to measure strain on a wires under the cushion of the seat to determine the weight of a person or thing seated. However, this design may not always measure all of the weight on the

seat, which may not be transmitted to the wires under the cushion, depending upon the position of the passenger.

SUMMARY OF THE INVENTION

[6] The present invention provides an improved system and method for generating a signal representative of a force, such as the weight of a person or thing on a seat within a motor vehicle, or the force applied to a switch on a vehicle steering wheel.

[7] The present invention provides a force measurement system utilizing active magnetostrictive sensors. The active magnetostrictive sensor includes an excitation coil and a detection coil. The excitation coil converts an electrical AC input signal into an acoustic wave by the magnetostrictive principle. The signal is AC to allow for a changing current through the coil, which when wrapped around a ferrite material creates an electromagnet. The acoustic wave travels through the ferromagnetic sensing material. The acoustic signal passing through the ferrite core creates an electrical current in the detection coil. When stress is applied to the sensing material, the acoustic wave is affected and the detection coil monitors this change. The change can be measured by measuring voltage or current. These methods require a constant excitation voltage/current. This change in the current/voltage, as measured from the detection coil, has a linear relationship to the amount of force applied on the sensing material. The sensor operates in a linear fashion as long as some force or "preload" is used to get the operating point away from the non-linear region. Preferably a pre-load is used in the present invention.

[8] The present invention provides a system for generating a signal representative of the weight of a person or thing seated within a motor vehicle includes at least one ferromagnetic element mechanically coupled between the structure of a seat and the vehicle floor, such that an elastic strain is induced therein responsive to all of the mechanical loading of the seat by the person or thing seated thereupon. Preferably, a ferromagnetic element is mounted directly between each seat bracket and the vehicle floor, in order to sense all of the weight

on the seat. The strain in each element is detected and measured by the detection coil, as described above.

[9] The present invention further provides a system for activating a horn. The ferromagnetic element is coupled to a contact surface, which is activated by a user desiring to activate the horn. The force exerted by the user on the contact surface is measured by analyzing the signal (voltage and/or current) received by the detection coil. If a predetermined change is detected by the associated electronics, the system activates the horn. This system provides a more constant force requirement across the area of the contact surface and under different operating conditions, such as temperature. Further, because the threshold can be adjusted in the electronics or software, the force required to activate the horn can be easily changed, such as for different vehicles or for user preference.

BRIEF DESCRIPTION OF THE DRAWINGS

[10] The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

[11] Figure 1 is a schematic of the force sensor system of the present invention implemented as a steering wheel switch and weight sensor;

[12] Figure 2 schematically illustrates an active force sensor according to the present invention;

[13] Figure 3 is a graph illustrating the operation of the force sensor of Figure 2;

[14] Figure 4a illustrates one possible arrangement of the force sensor of the present invention as a horn activation switch;

[15] Figure 4b illustrates another arrangement of a horn activation switch, similar to Figure 4a;

[16] Figure 4c is a third possible arrangement of the horn activation switch of Figure 4a;

[17] Figure 4d is a fourth possible arrangement for the horn activation switch of Figure 4a;

[18] Figure 4E illustrates a fifth possible arrangement for the horn activation switch of Figure 4A;

[19] Figure 4F illustrates a sixth possible arrangement for the horn activation switch for Figure 4A;

[20] Figure 5A is an alternate embodiment of the magnetostrictive sensor of Figure 2;

[21] Figure 5B is alternate embodiment of the magnetostrictive sensor of Figure 5A;

[22] Figure 6 is a more detailed view of the weight sensor of Figure 1; and

[23] Figure 7 is an alternate embodiment of the force sensor of Figure 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[24] The present invention provides a force sensing system 20 implemented here as a user activated switching system 22 and occupant weight sensing system 24 both utilizing a controller 26. The controller 26 includes a microprocessor 28 (including associated memory, storage, RAM, etc.) and any necessary signal processor 30, such as amplifiers, filters, analog to digital converters, etc. It should be noted that signal processing could be provided by the microprocessor 28 in a known manner. Generally, the user activated switching system 22 activates vehicle functions when selected by a user, while occupant weight sensing system 24 determines the presence, weight and/or position of an occupant in the vehicle.

[25] The user activated switching system 22 is illustrated as installed on a vehicle steering wheel 32 because this location benefits greatly from the present invention, although it should be recognized that the switching system 22 could also be utilized in other locations in the vehicle. The steering wheel 32 generally includes the steering rim 34 connected to the base or hub 36, which is mounted on steering column 38 and rotatable about its center line 40. The present invention provides a force sensor 42a mounted on hub 36, which is preferably for activation

of a vehicle horn, but could be used for other vehicle functions as will be described below. The force sensor 42a is preferably mounted behind the air bag module 44 as shown, but may also be mounted in front of air bag module 44. As is known, the air bag module 44 is selectively activated by air bag actuator 46, as determined by the controller 26. The controller 26 also controls other vehicle functions, such as the vehicle horn 48, headlights 50 and cruise control 52, based on activation of the force sensor 42a.

[26] In the user activated switching system 22, the force sensor 42a senses force imparted by the user upon the force sensor 42a, either directly or through airbag module 44 positioned in front of force sensor 42a. In response, the controller 26 activates the horn 48 or other vehicle functions, such as headlight 50 or cruise control 52.

[27] In the event of a crash, the controller 26 also selectively activates the air bag module 44 based upon inputs from the force sensors 42b and 42c (among other data inputs), which sense the weight of an occupant seated in vehicle seat 60. Preferably, force sensors 42b,c sense all of the weight between the seating surface 62 of vehicle seat 60 and the vehicle floor 64. In this example, the force sensors 42b,c are installed between vehicle seat 60 brackets 72 and the vehicle floor 64. It should be noted that the vehicle 60 in this example includes four brackets (two shown) and that sensors (two shown) would be installed between all of the brackets and the vehicle floor 64. The force sensed by each of the sensors 42b,c can be summed to determine the total weight upon seating surface 62. Alternatively, or addition, the controller 26 can determine whether occupant is seated toward the front of the seat, in the middle of the seat, toward the left or right of the seat 68, or whether there is no occupant in the seat 60.

[28] Utilizing known algorithm and rules, the controller 26 determines the occurrence of a crash, from crash detection sensor 76 (such as an accelerometer or ball and tube sensor). The controller 26 then determines whether to fire airbag module 44 based upon the severity or type of crash and based upon information from the sensors 42b,c. For example, if the controller 26 determines from sensors 42b,c that there is no occupant in seat 60, the controller 26 does not activate

airbag module 44. Further, if the weight on seating surface 62 is determined to be insufficient (the occupant may be a child) the controller 26 does not activate air bag module 44. Further, for a multistage airbag module 44, the controller 26 may determine which stages of air bag module 44 to activate, for more or less force, based upon the information from sensors 42b,c.

[29] Figure 2 schematically illustrates a force sensor 42 which could be utilized as the force sensors 42a,b and c of Figure 1. As shown in Figure 2, the force sensor 42 generally includes ferromagnetic sensing material 80, which receives the force to be measured (e.g. the force from the user to activate the user activated switch or the force from the weight of the occupant). The force sensor 42 further includes an excitation coil 82 and detection coil 84 each preferably wrapped about a ferrite core 86, 88 respectively. The ferrite cores 86, 88 are preferably abutting, adjacent the ferromagnetic sensing material 80 (or actually comprise the ferromagnetic sensing material 80, as described in other embodiments below). The function generator, preferably an AC sine wave generator 90 sends an excitation signal to the excitation coil 82. A bandpass filter/amplifier 92 is connected the detection coil 84. Function generator 90 and bandpass filter/amplifier 92 are preferably part of the signal processor 30 of Figure 1.

[30] The excitation coil 82 converts the electrical AC input signal onto an acoustic wave by the magnetostrictive principal. The acoustic wave travels through the ferromagnetic sensing material 80 and the ferrite core 88 of detection coil 84, which in turn creates an electrical current in the detection coil 84. When force or stress is applied to the ferromagnetic sensing material 80, the acoustic wave is affected by the change in strain in the material 80, as is the electrical current in the detection coil 84. The current (or voltage) is measured to determine the change. The frequency and amplitude of the signals and the number of turns in the coils 82, 84 will depend upon the particular application, as well the materials of the cores 86, 88 and the thickness, texture and shape of the ferromagnetic sensing material 80. One of ordinary skilled in the art would be able to determine suitable parameters for a given design.

[31] Figure 3 illustrates the RMS voltage output from the force sensor 42 in Figure 2 for a given force. Preferably, the ferromagnetic sensing material 80 (Figure 2) is mechanically preloaded so that the output verses force input is in the linear region. The threshold shown in Figure 3 could be for activation of the horn or other vehicle functions for the user activated switching system 22 of Figure 1. It should also be noted that the threshold can be easily changed by simply changing a software in the controller 26 thus, the sensor 42 can used for various applications and in different vehicle and can be easily configured to activate at the proper threshold.

[32] Figures 4a-f illustrate possible configurations of the force sensor 42a on a steering wheel 32a-f each comprising a steering rim 34a-f and hub 36a-f, respectively. In Figure 4a, the excitation coil 82 and detection coil 84 are positioned at opposite ends of ferromagnetic sensing material 80 on opposite sides of the center line 40 of the steering wheel 32a. Alternatively, as shown in Figure 4b, the excitation coil 82 and detection coil 84 can both be on the same side of the center line 40 of the ferromagnetic sensing material 80 in order to simplify the connection to the controller 26 (Figure 1). Of course, the excitation and detection coils 82, 84 could also be installed on different shaped hubs, as is shown in Figure 4c.

[33] Figure 4d illustrates an embodiment where multiple strips 80a-d are formed in the ferromagnetic sensing material (by cutout sections between the strips 80a-d). In this embodiment, the force on the strip 80a can be distinguished from force on strip 80b, c and/or d. Force on any one of the strips 80a-d will cause different changes in the signal received at detection coil 84, which can be discerned by the controller 26 (Figure 1). Varying the distances, widths, thicknesses, stiffnesses, textures, or other changes among the strips 80a-d will make it easier to discern activation of the different strips 80a-d. In this manner, each of the strips 80a-d can be programmed to operate a different vehicle function, for example the vehicle horn 48 could be activated by force on strip 80a, head lights 50 by force on strip 80b and cruise control 52 by forces on strips 80c-

d. (Figure 1). It should be noted that the embodiment of Figure 4d would preferably be installed in front of an air bag module.

[34] Figure 4e illustrates an alternate embodiment of a steering wheel 32e wherein the excitation coil 80e and the detection coil 84e are coiled about portions of the ferromagnetic sensing material 80e which constitute the ferrite cores 86e and 88e, respectively. In other words, in this embodiment, a separate ferrite core is eliminated and a portion of the ferromagnetic sensing material 80e is used as the ferrite core. It should be recognized that this could be implemented in any of the arrangements shown in Figures 4a-d, as well. This reduces the complexity and cost of the design.

[35] Figure 4f illustrates an alternate design for a sensor 40f including ferromagnetic sensing material 80f mounted on hub portion 36f of the steering wheel (not shown). Again, a portion of the ferromagnetic sensing material 80f is used to form ferrite cores 86f, 88f about which the excitation coil 82f and detection coil 84f, respectively, are coiled. The sensor 40f could be used in the designs of Figures 4a-e.

[36] Figure 5A illustrates an alternate magnetostrictive sensor 98 including an alternate ferrite core 86a, which could be utilized for the excitation coil 82a and detection coil 84a. The alternative ferrite core 86a generally comprises a cross having four posts 99 extending perpendicularly from ends of the cross. The coils 82a,b are coiled about the perpendicular posts 99. This sensor 98 could be used in the sensor designs of Figures 4a-d.

[37] Figure 5B illustrates an alternate magnetostrictive sensor 120 of the sensor 98 of Figure 5A. The ferrite core 126 comprises two u-shaped members 126, each having a cross-bar 128 and two perpendicular posts 130. The coils 82 a, b are coiled about the cross-bars 128. The cross-bar 128 of one u-shaped member 126 is positioned adjacent the cross-bar 128 of the other u-shaped member. This sensor 120 is easier to manufacture and could also be used in the sensor designs of Figures 4a-d.

[38] Figure 6 is an enlarged view of the weight sensor 42b of Figure 1 (weight sensor 42c would be identical). As shown in Figure 6, the ferromagnetic sensing

material 88 is mounted between the bracket 70 of the vehicle seat 60 and the vehicle floor 64, such that all of the weight on the seat 60 passing through the bracket to the floor 64 passes through the ferromagnetic sensing material 88. A fastener, such as a bolt 100, connects the bracket 70 to the vehicle floor 64, passing through an aperture 102 in the ferromagnetic sensing material 88. The excitation coil 82 and its ferrite core 86 may be positioned on one side of bolt 100, while detection coil 84 and its ferrite core 88 are on the opposite side. Alternatively, different arrangements could be utilized. For example, Figure 7 illustrates an alternate sensor 42g which could be utilized in place of the sensor 42b of Figure 6. In Figure 7, the ferromagnetic sensing material 80F (including aperture 102g) has portions 86g, 88g, which form the ferrite cores for excitation coil 82g and detection coil 84g, respectfully. Again, integrating the ferrite core in the ferromagnetic sensing material 80f reduces the number of parts and simplifies the design. This sensor design could also be used in the horn switch applications by designing the armature to fit into the sensor.

[39] All of the embodiments of the user activate switching system 22 (Figure 1) of the present invention offers three main benefits over current switch designs. The switches of the present invention will have relatively constant force thresholds over changes in operating conditions, such as temperature. Further, different locations on the steering wheel will also have a relatively constant force threshold, unlike current horn activation switches. Further, the sensitivity level can be easily adjusted by a change in software and controller (or change in circuitry in signal processor 30).

[40] The vehicle occupant weight sensing system 24 of the present invention measures all of the weight upon the seating surface 62, because sensors 42b,c are installed between the seat 60 and vehicle floor 64. The change in height of the seat is minimal, since it only the height of the ferromagnetic sensing material 80, which can be minimal. The electronics for this system, controller 26, is shared among the sensors 40b,c.

[41] In accordance with the provisions of the patent statutes and jurisprudence, exemplary configurations described above are considered to represent a preferred

embodiment of the invention. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope. For example, any of the pairs of excitation coil 82 and detection coil 84 could be replaced with a single coil that alternates as an excitation coil and detection coil.